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This is a final report on the research carried out under ARO grant DAAL03-91-G-0002, from November 1, 1990 through December 31, 1993, on the incorporation of a superlattice electron filter in a quantum well infrared (IR) detector to improve the detectivity of the device. It includes: (1) experiments measuring superlattice band structure parameters by vertical transport, (2) design and fabrication of Double Superlattice GaAs IR transistor, and (3) demonstration of device for background limited IR detection at T>77K.

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DOUBLE SUPERLATTICE GaAs IR TRANSISTORS

FINAL REPORT

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Double superlattice GaAs IR transistors

A superlattice structure can be incorporated into a quantum-well infrared detector as an electron bandpass filter to block electrons with energies higher or lower than the miniband energy. Electrons with energies inside the miniband can relax their energies to the lower edge of the miniband as they pass through the superlattice. Therefore, the superlattice not only filter the electron energy but also keeps the filtered electrons to a minimum energy. We have realized these expected advantages, greatly improved the detectivity of the device, and demonstrated the operation of a background limited IR transistor for T up to 90K. The research was carried out in these stages as described below.

I. Superlattice band structure by vertical transport

Hot-electron injection using a single-barrier injector and multiple quantum-well injector is studied and utilized to probe the superlattice miniband structure. The superlattice is placed in front of the collector of the device and the filter characteristics are determined by measuring the collector efficiency α as a function of the emitter bias V_E. Two results are obtained:

1. We find that the transmission in the minigap between two minibands is around 15% (not vanishingly small, around 1%, as expected). This is due to momentum randomizing scattering by impurities, reducible by improving the superlattice material.

2. The hot-electron distribution width in the $GaAs/Al_xGa_{1-x}As$ multiple quantum well structure is found to depend strongly on T in the T≈40 to 90K range. It increases with T, reaches a maximum at around 70K, and then decreases at higher T's. The experiment makes it possible to unambiguously identify thermally assisted tunneling as the dominant source of the dark current at 77K. This result indicated to us that further suppression of the dark current in the device at 77K can indeed be realized by designing the barriers between the quantum wells to more effectively suppress thermally assisted tunneling.

II. Design and fabrication of double superlattice $GaAs/Al_xGa_{1-x}As$ IR transistor.

In order to effectively reduce the thermally assisted tunneling component of the dark current for operation at 77K, we have designed a new $GaAs/Al_xGa_{1-x}As$ quantum well IR detector structure, in which the aluminum molar ratio of the quantum barriers increases in three steps and a narrow band-pass filter is placed in front of the collector. This barrier structure is able to more effectively suppress the dark current due to thermally assisted tunneling by providing a thicker effective barrier when the structure is under bias. In addition, the component of the dark current is largely eliminated by the bandpass filter.

III. Demonstration of background limited IR detection for T > 77K.

We have tested the IR hot electron transistor and measured its dark current, background photocurrent, its detectivity operating as a diode and as a transistor as a function of T. The %BLIP data are obtained from the measured photocurrent and dark current. At 60K, the collector shows 100% BLIP up to 3.8V while the emitter up to 2.3V. The range and %BLIP decreases with increasing temperature. At T = 77K, the conventional QWIP does not show any BLIP. The %BLIP of our new QWIP is 70%

BLIP at V_{BE} = 1V, and increases at lower bias. The bandpass filter in the collector increases the bias range of larger than 70% BLIP up to 2V. At T = 90K, the collector shows more than 70% BLIP for $V_{BE} \leq 0.8V$, while the emitter almost does not show any BLIP. The %BLIP in the useful operating range of the collector is larger than 90%, 70%, and 50% for T = 60K, 77K, and 90K respectively.

Publications

1. C.H. Kuan, D.C. Tsui, and K. K. Choi "Superlattice band structure probed by tunneling hot-electron injection," Appl. Phys. Lett. **61**, 456-458 (1992).
2. K.K. Choi, M.Z. Tidrow, M. Taysing-Lara, W.H. Chang, C.H. Kuan, C.W. Farley, and F. Chang, "Low dark current infrared hot-electron transistor for 77K operation," Appl. Phys. Lett. **63**, 908-910 (1993).
3. C.H. Kuan, D.C. Tsui, K.K. Choi, P.G. Newman, and W.H. Chang, "Hot-electron distribution in multiple quantum well infrared photodetectors," Appl. Phys. Lett. **73**, 2091-2093 (1993).
4. C.H. Kuan, K.K. Choi, W.H. Chang, C.W. Farley, and F. Chang, "Suppression of partition noise in infrared hot-electron transistors," Appl. Phys. Lett. **64**, 238-240 (1994).

Ph.D. Thesis

"Dark current and low-frequency noise in infrared hot electron transistors" by Chieh-hsiang Kuan, 1994.

Conference proceedings

1. "Background limited infrared hot electron transistor at 77K," C.H. Kuan, D.C. Tsui, K.K. Choi, W.H. Chang, C. Chang, and C. Farley, Device Research Conference, 1993.